Newsletter of the Arizona Geographic Information Council

The Perils of Groundwater Subsidence

This issue veers slightly from the usual format so that we may present the subject of subsidence. The accompanying articles were composed by the editor from interviews and materials provided by AMEC Earth & Environmental.

In the study of geology, the term *subsidence* refers to the natural process in which a broad area of the Earth's crust sinks, or becomes lower in elevation, without appreciably changing shape. This usually takes thousands of years and results in low-lying landscape features called basins.

A newer version of the phenomenon is sometimes called groundwater subsidence. It also results in the gradual lowering of relatively large areas, but it is measured in decades and is caused by the pumping of groundwater up to the surface. It is happening in Arizona, throughout the Southwest, and across the globe. It has already cost billions of dollars worldwide. The problem will only get worse as cities continue to grow, but fortunately it's a process that can be monitored, and measures can be taken to deal with it.

The Process

Beneath the ground, layers of sand and sediment are completely saturated with water. Every pore between the grains of dirt is filled with this water, which we call groundwater. It's not a thin layer just a few feet deep, it goes down for hundreds of feet. The water flows due to gravity, but it moves very, very slowly; it's moving through the spaces between the grains of earth deep underground. At points where groundwater reaches the surface it flows out to form natural springs, creeks and rivers. This is why rivers flow when it's not raining. The top of this zone of subsurface water is called the water table.

In areas of heavy rainfall or low elevation the water table may be just a few feet below the surface. In desert regions it's lower, but not drastically so in many cases. Back before the dams were built along the Salt River, the Salt was a large body of water that flowed all year. At that time the water table in the Valley of the Sun was perhaps ten feet down.

To meet the water needs of growing cities, groundwater is pumped up through wells. If the rate of pumping is greater than the rate of natural replenishment through rain and snow runoff, the volume of groundwater decreases and the water table gets lower. Subsurface earth that had once been saturated is now dry. Since the grains of dirt now have air between them instead of water, they naturally settle. This settling is gradual, widespread, and fairly uniform. It does not result in sinkholes. Rather, an entire region simply sinks, very slowly and imperceptibly, until the grains of earth become stable.

In the past 50-60 years, the region around Luke Air Force Base west of Phoenix has decreased in elevation by 17 feet. The "subsidence bowl" involved is about eight miles across. In Pinal County the Picacho area has dropped about ten feet over 40-50 years. Several other areas are in decline as well.

continued on page 3

Inside This Issue

Message from the Board

New Directions for AGIC

Tim Smothers
AGIC Vice President

Over the past several months, the Administrative and Legal Committee of AGIC has held two very interesting meetings focused on the future direction of AGIC. The theme of the meetings surrounded an effort to discover whether the existing AGIC framework is appropriate in this ever-changing world of technology. Members had expressed concern that the original AGIC mission and executive order may not meet the demands of our dynamic environment.

AGIC, established by executive order in 1989, had a defined role and structure that hasn't been updated (with respect to its role) since inception. These meetings were called in an effort for current board and committee members to review the past, evaluate the present, and focus on our future to build a work plan that speaks to our current calendar year and peers into the future.

The initial meeting was a rather aggressive affair; attendees were sequestered for the better part of a day, where all voices were heard. The morning's efforts allowed each participant to voice an opinion regarding the strengths and weaknesses of AGIC, while the afternoon was reserved to discuss direction, identify potential change, and focus on future work plan items.

Unanimous recognition of the success of the AGIC Conference was seen during the morning session. The efforts of the Conference Committee were applauded and all attendees saw this effort as a cornerstone of AGIC's endeavors. That being said, please join us at this year's conference in Prescott, August 8th through the 10th.

As technology evolves, so should our organization – or so was the thought during these sessions. Four major opportunities were outlined during the meeting; these opportunities are in tune with our current techno-environment as well as the original intent of the Board as spelled out in the executive order forming the Arizona Geographic Information Council. The opportunities outlined are:

- Promotion – AGIC should work to identify champions for geospatial technologies. As an enthusiastic group of geospatial professionals, the AGIC Board is uniquely suited to identify geospatial champions at many levels of government who recognize the importance of GIS and can assist in communicating AGIC's message to the state.
- Coordination – AGIC's broad membership and committee participation provide opportunities to assist in the coordination of matters geospatial. Although AGIC is not the end-all for geospatial processes throughout the state, it certainly is in a position to recommend and coordinate such processes as appropriate.
- Standards – As per the original executive order, AGIC has been identified as a key resource with respect to geospatial standard development for Arizona. Working with other key players to generate and review geospatial standards and practices has been identified as a key role for the board.

continued on page 3

AGIC Board Contacts

President
Tom Sturm
650-329-4326
tsturm@usgs.gov

Vice President
Tim Smothers
623-773-7671
timothy.smothers@peoriaaz.gov

Newsletter Editor

Jim Riedmann
623-773-7392
agicnews@yahoo.com

Previous issues of Surface Matters are available on the AGIC web site.

Surface Matters is the quarterly newsletter of the Arizona Geographic Information Council. It is written for those who want to stay in touch with the vision and activities of AGIC and with the continuing growth of GIS in Arizona.

Your comments about this publication are always welcome. Please send all correspondence to the editor.

Readers are invited to submit articles that they wish to be considered for publication. The author retains all copyrights. Please let the editor know if the article has been published elsewhere.

Arizona Geographic Information Council
1616 West Adams Street
Phoenix, Arizona 85007
Phone: 602-542-4060
agic@land.az.gov
http://agic.az.gov

Message from the Board
continued from page 2

- Issue insight – Board members have unique insights to the potential issues that surround the development of items geospatial. Using the board to provide recommendations for issue resolution is key to the enhancement of geospatial activities throughout the state.

Using these opportunities as a guideline in the development of this year's AGIC work plan, the Administrative and Legal Committee suggested several potential activities the board may enjoy tackling. These included:

- Continuation of the AGIC Conference (see you in August!)
- Development of an Executive Forum to promote GIS to decision makers around our state
- Coordination/promotion of the AGIC Data Portal/Clearinghouse
- GIS Champion identification
- Executive Order update – Bring the executive order out of the 1980s and ensure the verbiage and direction are consistent with current vision and technologies
- Committee Structure Review – Look into the potential for a flexible structure that fits our work plan motives ◇

These photos were taken on two consecutive days. The fissure gully in the bottom photo formed during a single, heavy rain storm.

Groundwater Subsidence
continued from page 1

Since the beginning of modern settlement in the greater Phoenix area, the groundwater level has dropped as much as 300-400 feet.

The Impact

Subsidence causes large regions to become lower in elevation, resulting in regional depressions compared to the surrounding terrain. One very expensive consequence in the long term will be to sewer and irrigation systems.

Many cities' underground sewer pipe systems are constructed with a slight degree of slope, which causes the water in the pipes to flow downhill. This is called a gravity system. It is efficient because it doesn't require pumps, or requires fewer pumps, to push the water through the system.

Large cities have underground pipe networks that extend many miles. Gradual sinking due to subsidence can cause the slope of the pipe network to flatten out, negating the gravity flow built into the system. This also applies to above-ground canals. Over the long term it could cost hundreds of millions of dollars to re-engineer existing systems to compensate for the diminished slope.

A second major consequence is flooding. As the topography of a region changes, so too does the path of water flowing over that topography. When a previously flat desert floor develops a depression of many square miles in extent, runoff is going to flow into that depression. The local flood regime will change. Floodplain maps, flood control structures, other infrastructure, insurance coverage and liability could all be affected.

A phenomenon related to subsidence is fissuring. A fissure is a tension crack that forms as a side effect of subsidence, initially appearing as a long, thin crack in the ground. At its beginning it may be less than an inch wide, but it can be hundreds or thousands of feet long and a hundred or more feet deep. Over time erosion can widen these thin cracks into deep gullies. In some cases a single storm event can wash so much dirt away that a large gully can be carved out in a few hours (see photos at left).

Fissures pose a serious threat to dams, levies and other water retention facilities. Long cracks in the earth can undermine these structures, requiring extensive repair. A similar threat is posed to roads, houses, and any other structures that find themselves undercut by fissures.

Groundwater subsidence is a real problem with real consequences. Fortunately it is also a slow process that can be monitored. Plans can be made and measures can be taken to combat it. ◇

How to Watch Subsidence

A Technical Review

The process of subsidence takes years to have noticeable effects and occurs over many square miles at once. How can such a broad, slow phenomenon be detected and monitored? Watching paint dry would make a person feel winded by comparison.

The key to observing subsidence is to approach the problem from many different angles using a variety of sophisticated techniques. AMEC, a worldwide engineering company with offices in Arizona, has recently been recognized for doing just that. The many methods the company uses are designed to detect, monitor, and potentially predict where subsidence and fissuring are occurring and to what extent they might continue.

Based in Great Britain, AMEC has offices across the globe, including 90 in the United States. In 2001, AMEC's Earth and Environmental office in Tempe contracted with the Maricopa County Flood Control District to perform analysis and remediation of McMicken Dam, an earthen flood control structure built in 1955 to protect Luke Air Force Base and nearby agricultural land from flooding by the Agua Fria River.

In 1979 it was discovered that fissures were forming not far from McMicken Dam. Over the ensuing years they crept ever closer. The Flood Control District sought to evaluate the threat, and in 2001 engaged AMEC to analyze the situation.

A subsidence investigation begins with a comprehensive geological appraisal of the region involved. This can encompass an area within a 20-mile radius of the target location. The aim is to understand the composition and structure of the land that's subsiding as well as the land surrounding it.

During this phase a high-tech satellite observation method is employed. Images using interferometric synthetic aperture radar, or InSAR, are gathered from a satellite operated by the European Space Agency. The satellite is in a polar orbit that comes back to the same spot over the Earth every 24 days. The satellite sweeps the area with radar beams and the data are processed into images called interferograms. Two such images, taken 24 days apart, can reveal vertical ground movement with a precision of *a few millimeters*. In this way subsidence can be detected.

To find new fissures that might be forming, more familiar methods are used: examining low sun angle aerial photographs and high resolution digital images. Sometimes fissures exhibit vertical offsets of a few inches; long shadows will reveal shallow linear features that aren't otherwise apparent. Because a new fissure might only be an inch wide, it could easily be covered by dirt or vegetation, hiding it from direct observation.

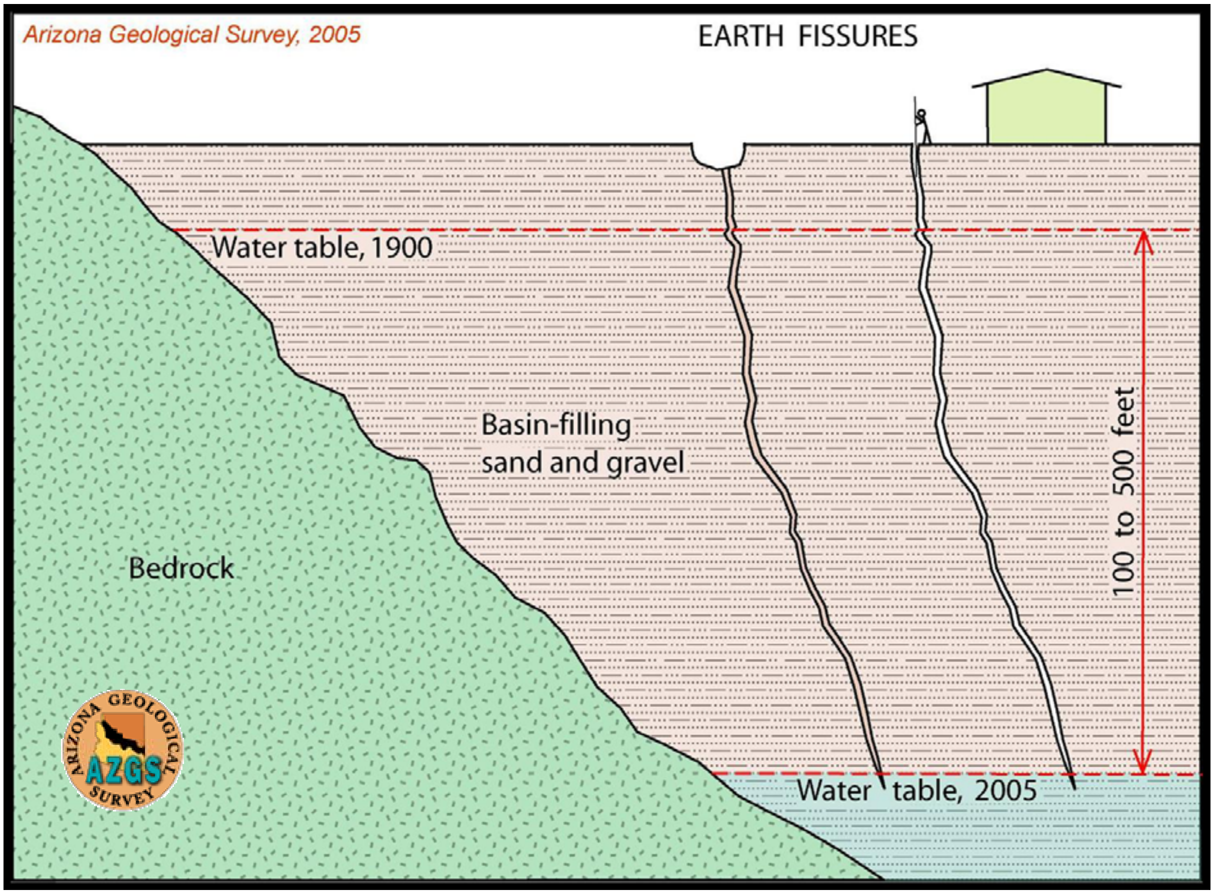
Once the regional assessment is done, local investigations get underway. These take place in a much smaller area, within a half-mile radius of the site of concern.

A battery of geological and geophysical tests is conducted to learn as much as possible about the local conditions. One or more trenches may be dug in a direction perpendicular to suspected fissures. A trench might be ten feet long or 100 feet long, and up to ten feet deep. Geologists enter the trench and look for a vertical crack in the wall that indicates a fissure. To get a hands-on look at the composition of the subsurface rock, bore holes are drilled and samples are brought up. The drill is a hollow tube which becomes filled with dirt and rock as it bores into the ground. It is then brought up and the sample is laid out to give a cross-section of the materials below. Gravity surveys are done to locate bedrock. Gravimeters can detect minute changes in the force of gravity from one spot to the next. Resistivity surveys, which involve putting electrical current into the ground, measure the differences in electrical resistance between subsurface rock layers. These surveys give clues to the composition and variation of earth materials deep underground. Finally, seismic studies are done to get a picture of the orientation of the rock structure below the surface.

Tying all of these investigations together is GIS. Everything that's done is put into a spatial framework. Field crews use GPS to take the position of every trench, every gravity reading, every everything. The points and lines depicting survey locations can then be combined with low sun angle photos, InSAR images, known fissure lines, and any other data available for the region. This spatial cohesion is immensely useful in understanding the geologic structure, composition, and behavior of the area of interest.

Once subsidence is confirmed, what can be done about it? In short, nothing. When the water table is lowered and the ground begins to settle, it can't be reversed. The only option is to fortify or rebuild structures that are threatened, and set up devices to monitor the movement. In the case of McMicken Dam, a 3000-foot section at the southernmost end of the dam was rebuilt in a new direction to remove it from a high-risk fissure area. An elaborate early warning system was then set up to monitor horizontal and vertical movements of the ground beneath the new section of the dam and across known fissures. When the system detects movement beyond a certain level, solar-powered transmitters send warning signals to the Flood Control District.

For its work on investigating the subsidence risk, devising a remediation plan, and setting up an innovative monitoring system, all of which took about five years, AMEC received the 2006 Engineering Honor Award for Water Resources from the American Council of Engineering Companies of Arizona. But that's not quite the end of the story. Back in the Tempe office are computer subsidence models that are constantly being updated as new data are gathered. The models seek to predict the amount of subsidence that may occur over time. At present they are looking 100 years into the future. The problem of subsidence will be with us for quite some time. ◇



Contributors

Brad Christensen, AMEC
Media Relations Director

Lawrence Hansen, PhD, PE, AMEC
Principal Geotechnical Engineer

Eric Priewe, AMEC
GIS Database Manager

Tim Smothers, City of Peoria
GIS Supervisor
AGIC Vice President

Brian Sovik, GISP, AMEC
GIS Manager

Ralph Weeks, PG, AMEC
Senior Geologist

Photo Credits
The fissure gully photos on page 3 were taken on county land within Maricopa County by **Ken Fiebelkorn** of the Queen Creek Public Works Department.

The background photo on page 1 and the illustration above are from the Arizona Geological Survey.

Further Information

For more information about subsidence and earth fissures, visit:

Arizona Geological Survey
www.azgs.az.gov

U.S. Geological Survey Science Topics
www.usgs.gov/science

The AZGS site includes maps of subsidence and fissure zones in Arizona.

The USGS site has further discussions of subsidence and methods used to study it.

AGIC Roundup

In an effort to ensure the success of the 2007 AGIC work plan – currently a work in progress – the board has approved the implementation of committee champions. These champions, made up of board members, are to assist in the development of realistic objectives for this year and beyond, work with current committee chairs and members to ensure progress is made, and ensure that communication channels are open amongst themselves and other committees.

The following committees and champions were proposed and accepted at the last AGIC board meeting:

1) Conference – Jami Garrison
   JGarrison@azdot.gov
2) Executive Forum – Adam Iten
   Adam.Iten@azdoa.gov
3) Legal/Admin – Tim Smothers
   Timothy.Smothers@peoriaaz.gov
4) Data Resources – Gene Trobia
   GTrobia@land.az.gov
5) Enterprise GIS – Gary Irish
   GIrish@land.az.gov
6) Outreach – Jana Hutchins
   Jana.Hutchins@asu.edu

The Conference Committee is in charge of all conference preparation and execution.

The Executive Forum Committee is a new committee that is interested in creating a forum that will bring representatives from different levels of government together to learn about current GIS issues and opportunities.

The Legal/Admin Committee is potentially looking at revising the AGIC Executive Order.

The Data Resources Committee focuses on compiling framework and other important data for the state.

The Enterprise GIS Committee was formerly known as the Technology Committee and will examine infrastructure for Data Portal, Clearinghouse, standards, etc.

The Outreach Committee is interested in the creation of a Geospatial Information Officer position and will work to find stronger champions within the Governor's Office. Other outreach activities fall under this committee as well.

All board members would like to invite interested parties to please contact a committee champion to be part of the geospatial development within our state. We have the opportunity to make a difference in Arizona's geospatial future. ◇

Calendar of Events

ESRI Arizona GIS Solutions Expo
April 4, 2007
8:30 AM – 4:00 PM
Pointe South Mountain Resort
Flagstaff/Goldwater Meeting Room
7777 South Pointe Parkway, Phoenix
http://events.esri.com/info

Tucson GIS Cooperative General Meetings
April 17, May 15, 2007
3:00 PM
City of Tucson IT Building
Pueblo Room
481 W. Paseo Redondo, Tucson
www.tucsonaz.gov/gis
The Tucson GIS Co-op meets the third Tuesday of each month at its regular location.

Eyes in the Sky Student GIS Showcase
April 28, 2007
9:00 AM – 12:00 Noon
Tempe High School Auditorium
1730 S. Mill Ave., Tempe
Free and open to the public
http://eyesinthesky.terc.edu

AGIC/ESRI Arizona Internet Mapping User Group Meeting
May 1, 2007
1:00-4:00 PM
Arizona Department of Administration
100 N. 15th Ave., Phoenix
http://events.esri.com/info

AGIC Quarterly Board Meeting
May 3, 2007
10:00 AM
ADOT Human Resources Development Center
1130 N. 22nd Ave, Phoenix
http://agic.az.gov/board/meetings.htm

AGIC Annual GIS Conference
August 8-10, 2007
Prescott Resort & Conference Center
1500 Highway 69, Prescott
http://agic.az.gov